Crust development on tilled sandy loam soils under natural rainfalls in northwestern Spain

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1. Abstract

Our study was carried out to observe the dynamics of crust development on sandy loam topsoil, under field conditions. Some features of micromorphological crust have also been analysed. Field experiments took place in agricultural plots (NW Spain) under two crop rotations: potatoes/winter cereal and maize/winter cereal. Soil crusting stages (estructural and sedimentary crust, thus intermediate crust stages) were recorded by visual assessment. In addition, other morphologic changes of the soil surface (roughness, macroporosity, and distance reached by runoff) also were evaluated. Semicuantitative observations of crust development provide a good indicating surface degradation. Sandy loam soils are susceptible to crusting by the effect of successive natural rains or single events when soil is bare. Depending on the intensity and the amount of accumulated rain on the surface in some cases sedimentary crust were originated. Although soil surface degradation increased with a each successive rainfall the most significant changes were observed after the heavy single events. The greater or smaller rapidity of the surfaces evolution was controlled to a great extent by the soil roughness and rain characteristics.To the time that the soil surface evolved by rainfalls effect, gradual decreases of the macroporosity and the roughness were observed. According to the soil surface conditions, diffuse runoff on different scales was generated. Micromorphologic analyses of a thin section of a sedimentary crust of these soils, showed that its thickness was less than to 1 cm and suggests the presence of elluviation phenomena.

2. Introduction

Soil degradation process can begin with surface crust formation. Surface crusting has been the focus of research on soil degradation for several decades and now remains a topic of great interest among the scientific community (Fox et al., 2004; Gallardo-Carrera et al., 2007). This phenomenon leads to land degradation and affects a wide range of agricultural land around the world (Usón y Poch, 2000; Robinson y Philips, 2001; Kunhn et al., 2003; Valentin et al., 2004).

In the tillage soils, crust formation is a complex phenomenon dominated by a wide variety of factors involving soil properties, rainfall characteristics, flow conditions and agricultural practices (Freebairn et al., 1991; Baumhart et al., 2004).

Surface crust development reduces the infiltration rates (Moore and Singer 1990) and soil roughness (Kamphorst et al., 2000), leading to an increase in runoff and to the speeding up of the erosive process. In addition, may inhibit seedling emergence and crop development (Rapp et al., 2000).

Crust classification varies in the literature but there is an agreement on two major types: structural crust and sedimentary crust. Breson and Boiffin (1990) showed that both types of crust correspond to two successive stages in general patterns of crust development. The change from the first to the second stage depends on the soils surface response to rainfall. These authors distinguished three main stages of surface crusting: initial fragmentary stage (F0), structural crust (F1), and sedimentary crust (F2). This classification has further been refined by including intermediate crust stages (F12) with more precise measurement of the relative proportion of structural and sedimentary crust, and the addition of a stage that corresponds to altered sedimentary crust (F3) (Ludwig et al., 1995).

In fields tilled the crusts formation on soil texture silty loam is very common and well documented. By contrast, sandy loam soils crusting is less remarkable, and although there are studies on this phenomenon, these are scarcer.

Taking into account these considerations, the aim of this study was to analyze in temperate and humid climate conditions: (a) the effect of the rain on the soil surface in cultivated soils with sandy loam (b) To describe the main micromorphological characteristics of a sedimentary crust developed in these soils.

2. Material and methods

Field experiments took place on agricultural plots in A Coruña province (northwestern Spain). The climate is temperate and humid, with an average annual rainfall ranged between 1000 mm and 1400 mm. Soils texture are sandy loam according to USDA criteria. In general**,** these soils are rich in organic matter, although their amounts are variable.

In a recently tilled soil surface, we monitored crust formation through time under natural rainfall. To evaluate the crusting stage, a methodology proposed by Bresson and Boiffin (1990) and improved by Ludwig et al. (1995) was followed. This procedure is found in other works (Le Bissonnais et al., 2005; Gallardo-Carrera et al., 2007). Stages of soil crusting were recorded by visual assessment, based on the estimation of the extent of structural, transitional and sedimentary crust. In addition, other morphologic changes of the soil surface referred to roughness, macroporoporosity and distance covered by runoff also were evaluated**.**

Two crop rotations were monitored: potatoes/winter cereal and maize/winter cereal. This experiment provided different sowing and rainfall conditions as well as a wide range of initial seedbed (*recently tilled soil)* in each crop during two years of study: potatoes (2 seedbed, 1 tilling in the vegetative cycle and 2 harvesting); winter cereal: (4 seedbed); maize (2 seedbed and 2 aporcados)

Using a scanning electron microscope (SEM) were observed some micromorphological features of the crust using thin section, which were prepared following the technique of Le Lay (1997). The images obtained helped rebuild a vertical sequence which encompasses the area of crust and the underlying material

3. Results and discussion

At the end of the observation period, the surfaces of these sandy loam soils presented to a greater or lesser extent signs of degradation as a result of accumulated rainfall. The speed and intensity of the state of degradation of the surface were determined by soil, climate and agronomic factors.

Cumulative rainfall values needed for the initiation and development of the successive stages of crusts were very variable. The semicuantitative data reflected in the table1 show that structural crust was formed on all surfaces, although one of them (winter cereal-seedbed) has not been possible to visualize. The amount of accumulated precipitation required for the development of this facies was highly variable, ranging between 36 mm and 81mm. The maximum degree of crusting (sedimentary crust continuously over 90% of the area), was observed in only six of the 13 initial surfaces, i.e. in three of the five surfaces created during the initial crop of potatoes; in 1 of the four surfaces sown with winter cereal and two of the four surfaces created after tillage and tilling durin vegetative cycle of maize, as reflected in Table 4.

The fact that rarely reached sedimentary crust is mainly related to two factors: (i) because during the vegetative development of the crop tillage is done leading to a new initial surface without enough time to elapse for development crust of sediment, (ii) the development of the crop is so fast, that the vegetation cover protects the surface of the impact of raindrops (e.g. winter cereal). For these reasons, the intermediate state of the crust are very common in these growing areas.

Table 1 Soil surface stages versus accumulative rainfall in agricultural fields with different crops

Crop	**Soil surface stages**	**Nº of surfaces in each stage**	**Accumulative rainfall** (mm)
Potatoes	Initial stage	2 seedbed 1 tilling in the vegetative cycle 2 after harvest	0 0 0
	Structural crust	2 seedbed 1 tilling in the vegetative cycle 1 after harvest	72.1 - 86.1 57.3 36.2
	Intermediate crust stages	2 seedbed 1 tilling in the vegetative cycle 1 after harvest	110.6 - 166.2 nd 98,7
	Sedimentary crust	2 seedbed 1 after harvest	176.3 - 221 140.9
Winter cereal	Initial stage	4 seedbed	0
	Structural crust	4 seedbed	66.1 - 68.7 - 73.4 - nd
	Intermediate crust stages	3 seedbed	107.9 - 113.7 - 122.3
	Sedimentary crust	1 seedbed	183
Maize	Initial stage	2 seedbed 2 tilling in the vegetative cycle	0 0
	Structural crust	2 seedbed 2 tilling in the vegetative cycle	70.9 - 87.2 36.2 - 41.7
	Intermediate crust stages	2 seedbed 2 tilling in the vegetative cycle	80.9 - 122.1 147.5 - 152.5
	Sedimentary crust	1seedbed 1 tilling in the vegetative cycle	182 196

For these soils, the amount of rainfall required for the sedimentary crust formation is high and ranged between 172 mm and 221 mm. As was observed intermediate stages of the crust with values ranging between 98 mm and 166 mm. On average, the kinetics of development of these surfaces is higher under the effect of single events that under high-intensity rainfall natural protracted but low- intensity.

To the time that the soil surface evolved by rainfalls effect, gradual decreases of the macroporosity and the roughness were observed. Significant variability in the distance achieved by runoff for the different combinations of soil surface and rainfall characteristics was observed. Thus, in the interril surface diffuse runoff was generated at different scales (centimetric, metric, decametric and hectometric), depending on soil surface in each agrarian situation.

In Figure 1 shows a thin section, which allows differentiate clearly two areas: (i) a continuous and dense layer on the surface, i.e. sedimentary crust which took place in a interrill area as a result of accumulated rainfall of 204 mm recorded since the initial state until the date of sampling, (ii) another layer below this i.e. underlying material or soil unchanged.

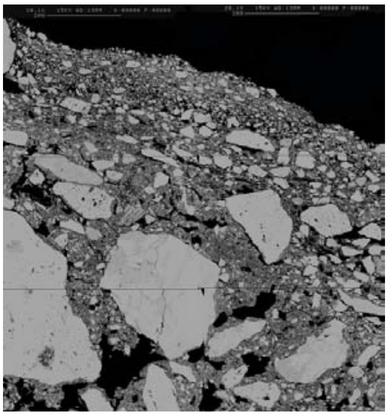

Figure 1 Section of a sedimentary crust and underlying material in the study area (SEM, x 20)

With regard to the crust, it was found that plasmic layer does not present, so that the particles of the skeleton tend to provide overlapping each other. The particle size corresponds basically to fine sand and silt, with relatively little abundant coarse sand. The porosity is very low, with pore size of less than 25 μ m. The thickness of the crust was 1 cm and was not composed of multiple layers, while in some areas appear to differentiate two bands but not there is a continuity of these.

As for the underlying material, grains and particles are involved in continuous mass of plasmic. The abundance of plasmic, as opposed to the shortage observed in the crust, suggests the importance of the phenomena of elluviation from surface levels. At the same time, the provision of plasmic on the surface of the particle skeletal material reveals underlying phenomena illuviation in this area.Contrary to the crusting layer, the underlying material presents a significant porosity, related to the low cohesion of this type of soils developed on granite. Moreover, the presence of gravel and coarse sand (3 to 4 mm) is common as reflected in the microphotography (fig.1).

4. Conclusions

The sandy loam soils in the Galicia region (Spain) are susceptible to the crusting by rainfall effect. The trend is to evolve, but the kinetics is interrupted by the high number of tillage that originate new initial stages before the full development of sedimentary crust.

The micromorphological crust is low- thickness (1 cm) and is not composed of multiple layers. The particles are arranged around the skeleton on other due to the absence of plasma and the porosity is very low. The underlying material is very porous and has a high content plasma phenomena which suggests elluviation from more superficial levels.

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